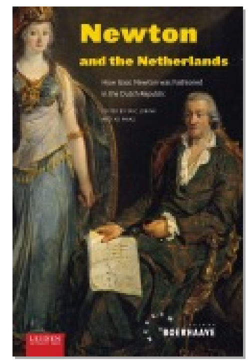
Newton and the Netherlands

Jorink, Eric, Maas, Ad



Published by Leiden University Press

Jorink, Eric & Maas, Ad.
Newton and the Netherlands: How Isaac Newton was Fashioned in the Dutch Republic.
Leiden University Press, 0.
Project MUSE., https://muse.jhu.edu/.

Low Country Opticks

The optical pursuits of Lambert ten Kate and Daniel Fahrenheit in early Dutch 'Newtonianism'

FOKKO JAN DIJKSTERHUIS

With the publication of the second edition of the *Principia* (1713), a wave of Newtonophilia washed over the Low Countries. Within a decade Dutch Newtonianism had been codified in the works of 's Gravesande, Van Musschenbroek and Boerhaave. Newton's *Opticks* was also part of this codification. After the revised English edition of 1717, the first French translation was published in Amsterdam in 1720. *Opticks* had a different position and was read in a different way than *Principia*. This article discusses the early reception of Newton's optics in the Low Countries, focusing on the cases of Lambert ten Kate (1674–1731) and Daniel Fahrenheit (1686–1736). The polymath Ten Kate was a key figure in the pious circle that first brought Newton to the Dutch scene and a prominent writer on physico-theological themes. The Gdansk instrument maker Fahrenheit was welcomed in this circle of Newtonians and pioneered in the public teaching of experimental philosophy.

Ten Kate and Fahrenheit were particularly interested in optics and given the context one would expect that Newton's optics played a decisive role in their pursuits. However, their reading of the *Opticks* turns out to have been rather liberal. They picked out the things that were relevant to their interests, they often did not get the gist of Newton's accounts, and they largely ignored the central claims of the *Opticks*. From the viewpoint of the *Opticks* this would indicate some deficiency in their understanding of Newton, but from the perspective of its readers it needs not. The main question then is not how well men like Ten Kate and Fahrenheit read and understood the *Opticks*, but how they approached it from the context of their intellectual and cultural interests.

The label 'Newtonian' is customarily used for the experimental philosophy that developed in the Low Countries around 1720 in the circle of 's Gravesande, Van Musschenbroek and Boerhaave. Histographically such a label is fraught with difficulties. By following the rather catholic way in which Ten Kate and Fahrenheit read and used Newton, I will try and reassess the idea of 'Newtonianism' and of 'isms' in the history of science in general. A body of ideas like that of Newton can be read on various levels and from various perspectives, depending on the particular interests and agendas of the reader. Even in the case of one and the same person – viz. Ten Kate – the way Newton was taken up could vary from role model in natural philosophy to a sounding board in phenomenal inquiry. Drawing on the lessons from the cases of Ten Kate and Fahrenheit, at the end of this article I will discuss some problems inherent to the idea of 'Newtonianism'.

An experiment from the *Opticks*

Lambert ten Kate came from a wealthy family of Amsterdam merchants in the Baltic trade. Originally he participated in his family's trading company but around 1705 he left business and devoted his time to his intellectual interests. These were vast. He was a prominent connoisseur and collector in the arts and sciences and wrote on a wide range of topics: aesthetics, linguistics, philosophy, theology.[1] Decisive for his epistemic and aesthetic outlook was his particular cultural background. He belonged to the liberal Mennonite congregation in Amsterdam, to which many of the early Dutch Newtonians also had close links.[2]

On 29 October 1716 Ten Kate carried out an optical experiment following an experiment described in Newton's *Opticks*. He was accompanied by his nephew, Jan Willink. The report of the experiment was published forty years later in the *Transactions of the Holland Society of Sciences*, by Johannes Nettis (1707–1777) who had been a student at the Mennonite seminary in Amsterdam.[3] The title of the article ran: 'Experiment of the Separation of Colours, Found by a Prism in the Order of the Musical Tones, Following an Experiment in Newton's *Opticks*: At the Time Observed and Now Reported from the Inheritance of Lambert ten Kate Harmenszoon'.[4]

The article began with a reference to the third proposition of book

1, part 2 of *Opticks*.[5] In this proposition, substantiated by two experiments, Newton divided the spectrum on the basis of the division of tones in the octave, arriving at seven symmetrically ordered colours.[6] Newton had already introduced the harmonic division of the spectrum in his optical lectures in 1670 and in a paper read to the Royal Society in 1675.[7] In the *Opticks* he had used it to account for the vexing problem of ascertaining the regularity of the dispersion of colours for which he had not been able to find an alternative solution.[8] Ten Kate explained that the specific division of the octave Newton used was less than optimal – making twelve out of sixteen consonants false. He proposed an alternative division that had only six false consonants. Although Ten Kate ordinarily used the diatonic scale, in this case he used the ancient Dorian mode that Newton had used.[9] According to him the eye could not see the difference between his and Newton's division. Given the greater perfection of his alternative division of the octave, Ten Kate held it for the most real as 'the more the Works of Nature are known, the more perfect they are found'.[10]

This was not all, however: Ten Kate had found a new and better way of investigating the colours of the spectrum. A prism produced only one 'rainbow of colours' and thus only one octave. In contrast, Ten Kate's new method could produce up to five separate spectrums at once, displaying the colours in a clear and orderly manner. The method only required a bowl of rich suds and a wine glass: dip the glass in the bowl, hold it on its side and study the thin film of soap. Coloured spectrums appear from the top, starting to come down gradually, and disappearing at the bottom. These can be studied conveniently. Ten Kate continued by asking how this phenomenon may be understood. After all, prismatic colours only appear upon refraction but 'here now however [the colour making of the rainbow] is displayed by this film reflecting, so wonderful, clear, and in its supreme degree, rainbow after rainbow, octave after octave: of which the solution is utmost peculiar'.[11]

Ten Kate knew the solution: when the glass is held on its side, the particles of the film begin to come down because of their weight; thus the upper part of the film becomes thinner and the lower part thicker, 'from which a most noble prism-shaped film is born'.[12] Because of the glueyness of the suds this takes some time. Therefore, the colours only gradually appear. The colours are produced by consecutive refraction, reflection and refraction of the rays of light at the front and the back

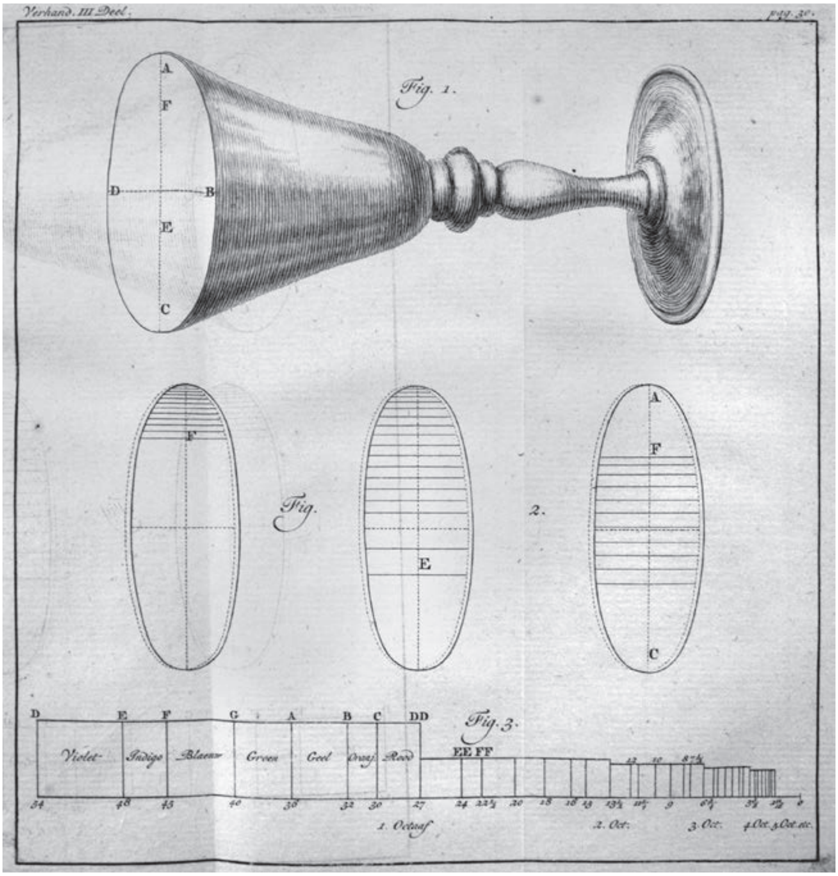


Fig. 1: Ten Kate's experiment on the separation of colours.

of the film. Ten Kate concluded by confirming that the colours are observed according to the harmonic order that he had introduced.

Ten Kate's account of the appearance of colours is interesting in the light of Newton's *Opticks*. According to him, the film of soap really produced 'rainbows of colours': the colours are produced in the same way as in drops of rain. In addition, he emphasized the *shape* of the film, arguing that it gradually acquired a prismatic cross-section. In this way he made clear that the spectrums in the soap film are truly prismatic colours. Newton, however, explained that the production of colours in thin films is different from that in prisms (or rain drops). In thin films some action of the rays affects the passage of rays of particular colours. This interference depends upon the length of the path of a ray through the film with respect to the position of the observer. In book 2 of the *Opticks* he had elaborately discussed the properties of the colours of thin films and showed the periodicity of the colours. Besides a quantitative phenomenological account, he also put forward a causal account in which the interaction between the ray and the surface of the medium produces 'fits of easy reflection and refraction' that enable or prohibit the passage of the ray at the other surface. Newton's theory of fits is notoriously obscure and was largely ignored by readers of the *Opticks*, so it is not a surprise that Ten Kate did not discuss it.[13] However, he took little notice of Newton's account of thin films altogether and apparently ignored the fundamental difference with prismatic colours.

The report of Ten Kate's experiment raises all kinds of questions. What inspired him to perform it? Why at this moment? Why did he want to correct Newton? How did he think his experiment added to Newton's doctrines? In order to make sense of the way Ten Kate responded to the *Opticks* we have to broaden our view a bit and see how Newton's optics was taken up in the circles around Ten Kate. This will also create an opportunity to discuss the reception of the *Opticks* more generally. In the history of early Dutch Newtonianism, the *Opticks* tends to have a secondary position in comparison to the *Principia*.

The *Opticks* in the Netherlands

Because Ten Kate gave a page number in his reference to the *Opticks*, it is clear that he referred to the 1706 Latin edition.[14] Whether he read *Optice* soon after its publication remains to be seen. In the summer of 1707 he began an extensive study of colour mixing together with his close acquaintance, the The Hague painter Hendrik van Limborch (1681–1759). Also involved in the research project was the painter and engraver Jacob Christoph Le Blon (1667–1741), who was working on what was to become the first method of colour printing.[15] The project lasted until 1713 and contained some inventive and original experimentation and conceptualization of colours and their properties.[16] Notably, no direct reference to Newton's optics was made in the course of the inquiry, not even to his doctrine of the heterogeneity of white light. The closest reference is in a letter of 3 February 1710, when Ten Kate mentioned 'mathematical experiments of the *prism*' to explain that blue is the weakest colour. Although the wording and the drift of the argument may suggest a reference to Newton, prism experiments as such were not exclusive to the *Opticks* and its author. Likewise, during the project no mention was made of Newton's account of colour mixing in the two propositions of *Opticks* following the harmonic division of the spectrum (to which Ten Kate responded with his '*proefondervinding*').[17] After Newton had proven how white light and shades of grey can be compounded of colours, he explained how the colours of paints are produced – by selective reflection – and how mixtures of paint produce compounded colours. Then he proposed a circle diagram to determine the position of a compound colour in the spectrum, based on the relative proportions of primary colours.[18] Despite Ten Kate's evident interest in optical themes directly related to the *Opticks* around 1710, he kept virtually silent on Newton at this time.

Ten Kate must have been, however, well aware of the existence and the content of the *Opticks* upon publication. His close acquaintance and early promotor of Newton, Jean Le Clerc (1657–1736) had favourably reviewed the *Opticks* in 1706. Le Clerc was professor at the Amsterdam Remonstrant College and published a learned journal discussing the latest developments in the Republic of Letters. The journal went through three series between the 1690s and the 1720s, *Bibliothèque universelle et historique*, *Bibliothèque choisie* and *Bibliothèque ancienne et moderne*. In the ninth issue of *Bibliothèque choisie*, Le Clerc presented the *Opticks* with a translation of large parts that ran over sixty pages.[19] He lauded Newton's experiments and discoveries, giving a faithful representation of the prism experiments and the doctrines of different refrangibility and the heterogeneity of white light. Equally interesting, however, is what Le Clerc left out. He skipped the mathematical and technical parts, referring his readers to the original. Newton's account of colours in thin films that comprised parts 1 and 2 of book 2 of the *Opticks* got only one paragraph in the review.

Le Clerc quickly moved on to the account of the colours of bodies that made up the rest of book 2. Propositions three to six, that contained Newton's harmonic division of the spectrum and his colour circle, he only mentioned without explaining the content. The whole idea of the colour circle thus did not become clear.[20] This predilection for Newton's doctrine of colours of bodies and disregard of his account of colours in thin films can also be seen with later Dutch Newtonians. 's Gravesande would do exactly the same in his *Physices elementa* (1720) and even integrated the doctrine of different refrangibility in the theory of colours of bodies.[21] In his review, Le Clerc discussed the queries at the end of the *Opticks* at some length and concluded with an exposition of what he regarded as Newton's exemplary method. Already at this point in 1706 the contours of the philosophical program of Dutch Newtonianism became visible.[22] Le Clerc stressed Newton's empirical bent and (thus) the purity of his philosophy as against Descartes', even at the level of the queries that Newton himself had presented as tentative speculations on the nature of things.

It is not clear when Ten Kate first went into the *Opticks* and neither can Le Blon's statement be substantiated that Ten Kate learned English with the purpose of reading the *Opticks*.[23] It might well be the case that Ten Kate only turned to the *Opticks*/*Optice* around 1716, ten years after its publication. In other words: on the wave of Newtonophilia that washed over the Dutch Republic from 1715. Part of the swelling Newtonianism was a publication of Ten Kate himself: *De Schepper en zyn bestier* (The Creator and His Rule, 1716). This physico-theological tract was a rendition of the *Philosophical Principles of Religion* (1715) by George Cheyne (1671–1743), an exposition of Newtonian natural philosophy. Ten Kate's edition was based on a summary by Le Clerc, to which he added extensive footnotes on mathematical issues, drawing on *Principia* and other mathematical works.[24] Although Cheyne had drawn substantially on the *Opticks*, Ten Kate's edition paid little attention to optics. He discussed the nature of light only with regard to the speed of light – and only by giving a reasoned value.[25] As regards colours he mentioned different refrangibility, listing seven original colours and suggesting the particle nature of light.[26]

Harmony in the senses

When in 1716 Ten Kate finally went into the subject matter of the *Opticks* seriously, he did not do so to preach the gospel of its master. On the contrary, his report was nothing more than a correction to Newton: first of the division of the spectrum, then of the experimental production of spectral colours. Ten Kate was not inexperienced in these matters. Far from that: in the preceding decades he had made profound study of both harmonics and colours. A manuscript from 1699 contains a study of the nature and production of sounds, in particular in human speech. Parts of this would be included in Ten Kate's *Aenleiding tot de kennisse van het verhevene deel der Nederduitsche sprake*, the groundbreaking study of linguistics he published in 1723. In this he also developed an account of musical harmony, thus providing the basis of his confident rebuttal of Newton. Then, in the late 1700s, he undertook the inquiry into colour mixing that was mentioned above. Ten Kate tried to develop a mathematical theory for the intensities of colours and developed a good deal of knowledge of the nature and proportionality of colours. So, he was no novice when critically assessing Newton's division of the spectrum. In this regard it is not surprising that he did not even mention the central claim of the *Opticks* about the heterogeneity of white light. It was not interesting for Ten Kate and besides, the idea that colours were not a modification of white light (and shadows) was not that new for artists and connoisseurs.[27] It was mainly interesting in the context of natural philosophy. In *Coloritto*, Le Blon in 1725 explicitly referred to Newton when he emphasized the difference with their accounts of colours: whereas he discussed material colours as they were used by painters, the *Opticks* concerned the 'impalpable' colours that mix into white.[28]

As it turns out, proposition 3 in book 1, part 2, of *Opticks* seized upon the very core of Ten Kate's interests. From a modern point of view these interests were quite disparate: linguistics, art theory, physico-theology, to name a few. As a result, the assessment of Ten Kate's contribution has been rather fragmented in historiography with historians of linguistics, art, science, philosophy each cutting out the relevant parts of his story. Only one or two have asked whether some kind of inner coherence in Ten Kate's work can be found.[29] Ten Kate was searching for harmony, in terms of regularity, beauty and piety. This was not, however, the classical Pythagorean harmony and its Renaissance renewal. First of all, Ten Kate combined the study of the classics with empirical and mathematical investigations of spoken languages, statues and drawings, and light and colours. Secondly, harmony for Ten Kate was not so much in the world – *in* Nature – as in the senses, in our perception of the world. This conviction was rooted in his aesthetical ideas that stressed the way in which art evoked religious experience.[30] This phenomenological conception of knowledge and emotive aesthetics was rooted in Ten Kate's liberal Mennonite milieu in which devotion was sought in the ordinary.[31]

Ten Kate's search for harmony and his particular epistemic outlook found expression in a broad spectrum of inquiries, starting in 1699 with a study of phonetics.[32] In the colour-mixing project with Hendrik van Limborch, it gave rise to a series of investigations of light and colours that is quite remarkable in the history of optics. They determined the relative clarity of colours by comparing gradations of colours with painted patterns of coloured and white/black lines, that from a distance are perceived as uniform colours. The number of lines then gave a measure of the power of a colour. This experimental set up was quite original and draws attention to a perceptual approach in optics that is largely ignored by historians of early modern optics.[33] Against this background of a particular research agenda and specific experiences in optics, Ten Kate responded to the *Opticks* in 1716. That is, he picked out a specific claim of Newton that he juxtaposed to his own convictions and experiences. A similar purposive reading of the *Opticks* is found in the work of the second protagonist of this story.

Fahrenheit

Not long after his experiment on the separation of colours, Ten Kate introduced a newcomer to the circle of Amsterdam amateurs: Daniel Gabriel Fahrenheit. Fahrenheit has acquired fame as a maker of instruments, thermometers in particular, and as a lecturer on experimental philosophy. In a letter to Le Clerc, Ten Kate wrote: 'there is here in Amsterdam a man named Fahrenheit who makes all kinds of barometers, thermometers, with far greater precision, for the use of physicists'.[34] Le Clerc published the letter in the issue of his *Bibliothèque* of that year, thus advertising the qualities of Fahrenheit and his instruments to a broader audience. The letter described in detail the instruments and the methods Fahrenheit used to assure their accuracy and reliability.

The emphasis of Ten Kate's letter was on an exotic phenomenon sometimes observed in the containers of vacuum pumps and barometers: a luminescence also called barometric light. In the early eighteenth century this phenomenon had become well known and was studied by savants all over Europe.[35] Barometric light was first observed by Jean Picard (1620–1682) in 1675: when mercury in a glass tube is shaken a band of light appears on the glass at the meniscus of the mercury.[36] The phenomenon requires very clean glass and very pure mercury and was difficult to reproduce until Johann Bernoulli (1667–1748) in Groningen invented an instrument to control it, Ten Kate explained.[37] Fahrenheit also made instruments called 'ethereal phosphors' and had improved the design. Ten Kate's account served on the one hand to demonstrate the high quality of Fahrenheit's instruments. On the other hand, Ten Kate appealed to the learnedness and interests of Le Clerc, pointing out that the editor of the *Bib-*

liothèque was familiar with the phenomenon and its history. Ten Kate concluded his letter by pointing out other instances of phosphorescence and the importance to find an explanation of the phenomenon. The emphasis on barometric glow did not only appeal to Le Clerc but also reflected the particular interests of Fahrenheit in chemical issues in natural inquiry.

Fahrenheit had recently arrived in Amsterdam, probably during the second half of 1717, but he was familiar with the city. Having been raised and orphaned in Gdansk, he had been brought to Amsterdam in 1702 to become an apprentice in the Van Beuningen house of merchants in the Baltic trade. As Ten Kate had also been a partner in a merchant house that traded with Gdansk and other Baltic towns, it is possible that he and Fahrenheit had made their acquaintance in those days. In 1707 Fahrenheit left business to pursue his interest in natural philosophy and embarked on a ten-year journey through the Scandinavian, Baltic and German lands. During this journey he visited Ole Rømer (1644–1710) in Copenhagen – who had developed a mercury thermometer – Gottfried Leibniz (1646–1716) in Hanover and Christian Wolff (1679–1754) in Halle. In 1717 he returned to Amsterdam, probably because the prospects for patronage in Germany had vanished. He established himself as an instrument maker and soon started to give lectures to paying attendants, which he would continue until his death.[38] These lectures are quite instructive as regards the way Newton's *Opticks* was presented to the circle of early Newtonians.

Fahrenheit's lectures are quite well documented in a prospectus from 1721 and a collection of lecture notes.[39] The lectures consisted of two series on Wednesdays, one of fifteen meetings on hydrostatics from 3:00 to 5:00 in the afternoon, and one of sixteen meetings on optics from 5:30 to 7:30 in the evening. They were announced with the following words: 'The method to demonstrate natural sciences that are attached to mathematics by means of "experimenta" or tests is undeniably the best'.[40] Fahrenheit said he used 'the best French and Latin writers' and for hydrostatics he particularly named Boyle's *Paradoxa* and 's Gravesande's *Physices*. He did not mention Newton at this point. The series of lectures on optics started with a general exposition of the nature and properties of light and its rays, quickly moving on to refraction and lenses. Dioptrics and the design of refractors comprised nine lectures, followed by five lectures on catoptrics. It is clear that Fahrenheit's principal interest in optics concerned instruments.

The lecture notes start with four unnumbered folios headed 'Introduction' that appear to have been inserted separately, considering the size of the leaves and the style of writing. This introduction described some experiments with coloured fluids, including observations through a prism, and the 'ethereal phosphors'.[41] The actual lectures on hydrostatics and optics are on numbered pages and the latter starts with an exposition on the nature of light in which the 'ethereal phosphors' return again. Fahrenheit took a non-committal stance regarding discussions about the nature of light, although in the course of his lectures he expressed sympathy for Descartes several times. His main goal, however, was to explain the properties of light and his principal interest was the design of instruments and chemical phenomena. He offered an experimental discourse in which propositions (like the law of refraction) were proven by experiments. Fahrenheit was particularly interested in the colours of bodies and the way these could be investigated by prisms. In this regard, he referred approvingly to Newton. He stressed the specialist nature of the *Opticks*, explaining that it demanded a considerable knowledge of optics.[42] He explicitly left out mathematical analyses, referring his audience to the dioptrics of Nicolaas Hartsoeker (1656–1725). This is interesting because Hartsoeker was professedly anti-Newton and had written a critical letter in response to Le Clerc's lauding review of Cheyne.[43] Colours in soap films are mentioned as well, with a brief explanation of the effect, but the account is too brief to establish a link with Ten Kate.[44]

Fahrenheit discussed all kinds of optical instruments, practical as well as entertaining. In the last lecture on catoptrics, he discussed instruments with mirrors. Here Newton finally got centre stage. Fahrenheit first explained how a refracting telescope could be shortened by use of plane mirrors, before coming to Newton's invention of a telescope with a concave mirror objective. In his view the main advantage of Newton's reflector was the shortening of telescopes. In the course of the seventeenth century, refracting telescopes had gradually become too long to handle, reaching lengths of ten metres and more. Fahrenheit did not mention chromatic aberration, which had been Newton's principal goal of designing the instrument. He was well aware of chromatic aberration, having explained that the reddish appearance of telescope images was caused by the shorter focal distance for blue rays. In an earlier lecture he had discussed chromatic aberration in greater detail. In a rather lengthy exposition on refracting telescopes,

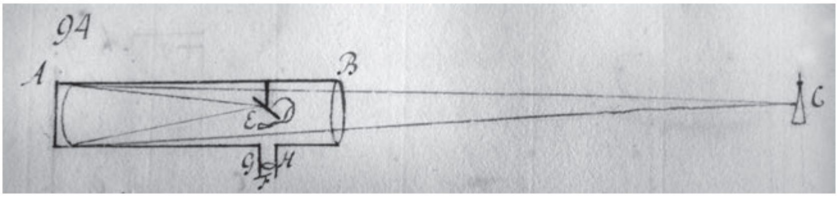


Fig. 2: Fahrenheit's sketch of a Newton reflector. (Source: Leiden University Library, BPL 772, fol. 51v)

he had explained that Newton in his *Opticks* had proven with accurate experiments that colours are differently refrangible and argued that this was the reason of the poor performance of telescopes. However, Fahrenheit surprisingly added, Newton only aimed at Galilean telescopes (consisting of a convex objective and a concave ocular), thus implying that the effect was less relevant in the Keplerian telescopes (consisting of convex objectives and oculars) that were common in astronomy.[45]

Fahrenheit closed the lecture by discussing a reflecting telescope and microscope of his own design. According to the notes he had said the following:

> After I had read Newton's *Opticks* about nine years ago, the composition of the preceding telescope pleased me so much that I looked for an opportunity to make one mechanically. And as Newton complains about the metal as well as the glass, I chose about six years ago a hardened steel for the objective mirror of six-inch focal distance, Rhineland measure. And as it seemed to me to be a bit awkward in use to look into the mirror from the side, I made a round hole in the middle of the mirror and furthermore I placed a small convex mirror on such a distance from the objective mirror, so that the rays of objects that were reflected by the large mirror bounced off for a second time to the hole in the large mirror, where the rays were thus gathered into an image.[46]

There is no diagram to this description, but it is clear how Fahrenheit had taken up the *Opticks*. Not as a foundational exposition on the nature and properties of light and colours and not as a primer on the design of optical instruments, but as a challenge to his instrument-making skills. Reading about Newton's reflector, he immediately considered ways of improving the material properties of mirrors and configuring mirrors and lenses to make telescopes more convenient to use.

The challenge had presented itself a couple of years earlier, most probably when Fahrenheit was staying in the German countries. If the lectures took place from 1721 on, his statement that he worked on mirrors six years prior accords pretty well with a letter he wrote to Leibniz on 1 July 1716 in which he said he had just built his first reflector.[47] This would imply that he first read the *Opticks* around 1713. Probably it was not before 1714, after he had arrived in the German countries from Copenhagen. His biographers suggest that Fahrenheit did not start to work on mirrors prior to his stay in Berlin, Halle, Leipzig and Dresden from 1714–1716.[48] Fahrenheit had gone to these German towns to improve his skills in glass-working for the purpose of making thermometers. His plan paid off, for he became one of the best blowers of capillary tubes.

Circumstantial evidence may shed some more light on the development of Fahrenheit's interests and his involvement in mirrors in particular. From the 1690s Ehrenfried Walter von Tschirnhaus (1651–1708), a nobleman in the patronage of the Saxon Elector, had made substantial efforts to improve and modernize the Saxon glass industries.[49] Besides promoting the economic interests of Saxony, Tschirnhaus was particularly interested in developing technologies for making high-quality burning mirrors. Burning mirrors had been central to his interests since his extended sojourns in the savant circles of the Dutch Republic, Paris and London between 1668 and 1682.[50] He had experimented with mirrors, considered the physics of light, and developed the mathematical theory of caustics, on which he corresponded extensively with men like Christiaan Huygens and Gottfried Leibniz. After the death of Tschirnhaus his mirrors remained in the Dresden Kunstkammer and the optical manufacturing techniques were further developed in the Saxon glass huts.[51] We may surmise that Fahrenheit encountered this legacy on his visit to Dresden. A direct link does not exist, but there are several indirect links between Fahrenheit and Tschirnhaus such as the latter's Dutch network and of course Leibniz. Such circumstantial evidence suggests that Fahrenheit's interest and expertise in reflectors was spawned by Saxon mirror-work.

These speculations aside – but I do feign hypotheses – the biography of Fahrenheit offers an important lesson regarding the influence of Newton. The formative years of Fahrenheit's experimental method and his instrumental proficiency took place in the vicinity of men like Rømer, Leibniz and Wolff. Skilled and learned, he arrived in Amsterdam in 1717, finding a natural place among the Amsterdam 'Newtonians'. In this development, Newton's *Opticks* was a source of inspiration, but not at all the cornerstone of Fahrenheit's optical pursuits. Some of it was relevant to him, but the natural philosophy hardly interested him. The same goes for Ten Kate; he too read the *Opticks* from his own particular points of view. They were well-versed in optics and picked out the parts that were relevant to their interests – the harmony of colours, the perfection of instruments. What does this all mean for Ten Kate's and Fahrenheit's alleged 'Newtonianism'?

Not all roads lead from London

The optical pursuits of Ten Kate and Fahrenheit can easily be read as examples of deficient reading of the *Opticks*, containing many misunderstanding, ignoring the gist of Newton's argument, and so on. This would imply that something like Newtonian optics existed and that it was a principal point of reference for the early Dutch Newtonians. The cases of Ten Kate and Fahrenheit raise some fundamental difficulties with such an interpretation. Theirs are not stories of the reception of some coherent body of knowledge, but of purposeful appropriation of particular elements within a broader spectrum of ideas and practices. The cases of Ten Kate and Fahrenheit bear upon the early stages of so-called Dutch Newtonianism and have, I believe, historiographical implications for the very idea of 'Newtonianism'. In the historiography of eighteenth-century science terms like 'Newtonian' and 'Newtonianism' are rather common and often used in an uncritical way. Ten Kate's linguistics is generally characterized as 'Newtonian', as are the pursuits of many Dutch savants of the period. In my view, however, the use of such a designation is not enlightening and often misleading in terms of historical understanding. In the final part of this article I want to seize the opportunity and discuss some problematic aspects of the idea 'Newtonianism'.[52]

Until quite recently the term 'Newtonianism' was used in a wide range of meanings, ranging from a physical theory, to a methodology and a philosophical system.[53] The free use of the label suggests some coherent system of knowledge. In early modern conceptions this would be a system of natural philosophy, comprising ontology, epistemology, cosmology and metaphysics.[54] In many cases, however, such systems have been narrowed down to physical theories and methodological positions, neglecting the broad scope of natural philosophy in both philosophy and subject matter.[55] Efforts have been made to precisely define such a system, resulting in a collection of brands of 'Newtonianism'.[56] Apart from the question to what extent it is historiographically legitimate to characterize 'Newtonianisms' in terms of physical theories, such exercises leave open the question to what extent a 'Newtonianism' has agency.[57] First of all, no 'school' of natural philosophy came into being before the late eighteenth century. Second, a *system* of natural philosophy rarely if ever was a main point of reference for natural inquirers. Ten Kate and Fahrenheit provide cases in point. They adopted elements of Newton's teachings – a physical explanation, an experimental find, an inventive artefact, a metaphysical idea – but were largely indifferent to his system of natural philosophy as a whole. Not all praise for or critique of Newton should be understood on the level of natural philosophical systems. Often inquirers had a different agenda that concerned specific empirical, mathematical or technical issues.[58] 'Newtonianism' does not seem a very fruitful category for doing history of science.[59]

A second problem in the use of 'Newtonianism' is the tendency to focus exclusively on Newton when interpreting early-eighteenth-century science, neglecting other big names like Boyle, Leibniz and Wolff. However, Newton was not the prime mover of eighteenth-century experimental philosophy. The Republic of Letters offered a broad spectrum of ideas, convictions, examples and things to the natural inquirer who created assemblages fitted to his needs. Schofield has argued that the spectrum of references was much broader for the Dutch, and that Newton was relatively secondary for the Swiss and French. In his taxonomy he effectively deconstructs the 'Newtonian' nature of most of the Newtonian brands.[60] The experimental philosophy that is labelled 'Newtonian' had been taking shape well before Newton entered the scene. Wiesenfeldt has shown how at Leiden University an experimental physics was established in the 1670s, primarily in response to the ongoing debates about the status of philosophy.[61] His discussion of De Volder shows that later 'Cartesianism' was quite empirical, which is confirmed by 'post-Cartesians' like Rohault.[62] Likewise, at Halle Wolff continued a tradition of experimental teaching that had begun by Johann Christoph Sturm (1635–1703) at the University of Altdorf. Not coincidentally, Halle was one of Fahrenheit's stopovers in the German states. Taking contexts like these will seriously yield a much richer historical picture.

The term 'Newtonianism' is often used in terms of *reception* of Newton's doctrines, suggesting a one-way traffic from a given set of doctrines to an attentive audience. Closer inspection of early Dutch 'Newtonianism' makes clear that the process was far from unidirectional. It was largely a joint venture of Desaguliers and 's Gravesande in their to-and-fro between England and the Dutch Republic, linking receptive circles in both places. The second edition of the *Principia* was pivotal, but it was also a creative appropriation of Newton's original mechanics, including the 'Newtonianization' of Newton himself by his English circle of devotees. Rienk Vermij has shown in a brilliant article how a particular group of pious but freethinking Amsterdam amateurs adopted Newton around 1715 as the banner for their philosophical and theological convictions.[63] In this process the term 'Newtonian' acquires actual historical significance and was indeed an actor's category. Yet it was used for a specific purpose, as a label to distinguish a particular conception of natural philosophy, and to its theological aspects in particular. 'Newtonianism' as used by early Dutch Newtonians was the physico-theological program that mobilized the pious response to the allegedly atheist implications of Descartes' and Spinoza's mechanistic philosophies.[64] In other words, 'Newtonianism' is a theological/philosophical concept that should be carefully distinguished from astronomical, physical or chemical theories. If the label 'Newtonianism' has any historiographical value, it is as the ideological label in the way the Dutch Newtonians used it.

The rhetoric used to separate the new philosophy from the Cartesian (and Spinozist) threats of atheism was loud and persuasive. At the same time it obscured the ideas and practices they had developed on their own, as well as the other sources of inspiration and justification like Rohault, Huygens, De Volder and Wolff. Central to the Newton-rhetoric was the requirement to deduce propositions from the phenomena, as contrasted to the rationalist speculations of Cartesians. Significantly, in their rhetoric they used the name of Boyle almost as often as Newton to mark off the despicable Descartes. Boyle fitted the physico-theological ideology of the 'Newtonians' perfectly, but he also provides a much earlier source than Newton and a direct link with the previous pursuits of De Volder. Moreover, the reference to Boyle points to the conspicuous interest in chemistry among the Dutch 'Newtonians'. An example of this is the particular attention Ten Kate gave Fahrenheit's 'ethereal phosphors' when introducing him to the Amsterdam circles. Likewise, in the *Opticks* Ten Kate and other 'Newtonians' singled out Newton's theory of the colours of bodies in particular. This chemical context was quite significant from 1700 and should be taken into account when considering the development of 'Newtonianism'. Early modern chemistry has a history of its own that sheds new light to the development of experimental physics and the role of Newton.[65]

In optics too, the Dutch 'Newtonians' had different sources of inspiration prior to Newton. In its early days, Vermij's circle of Amsterdam amateurs had been a principal promoter of Tschirnhaus. Le Clerc and Ameldonk Blok (fl. 1687) saw to the publication of Tschirnhaus' 'Medicinae' and their prompt translations. They had a particular interest in his optical projects, advertising and circulation burning mirrors and lenses of his. The connection I hypothesized between Fahrenheit and Tschirnhaus was probably not coincidental. Finally, the same circle had been instrumental in promoting the optical works of Hartsoeker in the 1690s. Despite the fact that Hartsoeker turned against Newton in 1712, to the audience of his lectures Fahrenheit recommended him in optics. However, in the 'Newtonian' rhetoric of the 1710s and 1720s such diverse sources of inspiration largely disappeared from view.

Ten Kate would vehemently advocate Newton against Descartes for it in *De Schepper en zyn bestier*. Still, he did not need Newton to become an empiricist. He already was long before Newton came to his attention. Ten Kate had developed his empirical approach to linguistics from the late 1690s onwards.[66] The label 'Newtonian' fitted his empiricism – proposing and proving properties from phenomena – but with respect to Newton's account of the nature and properties of light, he was rather liberal. His phenomenological approach to nature did not quite fit Newton's analytical optics and the ontology of his theory of sound was entirely at odds with Newton's doctrines. These did not disappear after 1716. Very few Dutch Newtonians were orthodox in any sense of the word. 's Gravesande and Van Musschenbroek explicitly used hypotheses; in a circumspect manner but still introducing speculative elements in experimental philosophy.[67] 'Newtonian physics' had many features that were rather non-Newtonian, like the predilection for pumps and hydrology 's Gravesande and Van Musschenbroek shared with Desaguliers, and a focus on chemistry. In optics too, the Dutch 'Newtonians' put emphasis on specific themes – the colours of bodies, the nature of light – that transformed Newtonian optics into a new entity. Newtonian about their philosophy was mostly the ontology of particles and forces. Compared to Ten Kate and Fahrenheit, 's Gravesande and Van Musschenbroek were more occupied with building a system of natural philosophy, but this was primarily because they wrote textbooks.

Newtonian *Opticks*

If there was something like Dutch 'Newtonianism', it was primarily linked to the second edition of the *Principia* and the ideology of pious natural philosophy. In the history of Dutch 'Newtonianism', the *Opticks* is relatively overshadowed by the *Principia*. My account of the reading of the *Opticks* somewhat shifts the perspective from philosophical systems and worldviews to ingenuity and materials. In optics natural philosophical issues of God and Nature were less prominent. Although I have confined my discussion to the intellectual aspects of 'Dutch Newtonianism', it can be questioned whether this can be approached as a set of ideas at all. Interpreting early Dutch Newtonianism – and Ten Kate's and Fahrenheit's pursuits in particular – as material culture may be historically illuminating.[68] Yet even from an intellectual perspective it is clear that the 'recipients' of Newton's optical doctrines actively appropriated their readings to their own causes. They possessed considerable expertise in matters of optics and this shaped the way they took up the *Opticks*. 'Newton's optics' was not ready-made to be exported; it was read and thus made, in the Low Countries too.

Despite the enthusiasm for Newton's optics and despite the large amount of publications in Dutch on experimental philosophy, *Opticks* was never translated into Dutch. By the time the second, enlarged edition of *Opticks* appeared in 1717, the Low Countries had been flooded by the tsunami of Newtonophilia. This new edition was 'Newtonianized' in a similar way as the second edition of *Principia*, emphasizing its epistemological and ontological outlook.[69] In 1720 the first French translation was published in Amsterdam. It was followed by a second edition in Paris, to which Newton himself exerted his authority by making its 'Newtonian' message unmistakable. Eventually, *Opticks* made it to the Dutch language via a considerable detour. In 1753 the Amsterdam printer Isaak Tirion (1705–1765) published a Dutch translation of Robert Smith's *Compleat System of Opticks*. This was a carefully structured textbook on optics, in which the *Opticks* was the foundation of the physical part. But Smith, too, appropriated Newton's doctrines to his own didactic interests.[70] A direct Dutch translation of *Opticks* was never made and so a *Gezigtkunde* never saw the light.

Notes

1 L. ten Kate, *Gemeenschap tussen de Gottische spraeke en de Nederduytsche* (Amsterdam 1710); L. ten Kate, *Den schepper en zyn bestier te kennen in Zyne schepselen, volgens het licht der reden en wiskonst* (Amsterdam 1716); L. ten Kate, *Aenleiding tot de kennisse van het verhevene deel der Nederduitsche sprake* (Amsterdam 1723); L. ten Kate, *The beau ideal, by the late ingenious and learned Hollander Lambert Hermanson ten Kate, translated from the original French by James Christopher Le Blon, author of the* Coloritto (London 1732). Ten Kate wrote a manuscript treatise on phonetics in 1699, parts of which appeared in the *Aenleiding* of 1723, his major publication on linguistics. A transcript of the manuscript by Cornelis Ploos van Amstel is in the library of the University of Amsterdam: L. ten Kate, 'Verhandeling over de klankkunde', Library University of Amsterdam, 63 U.B. I.C. 21. The manuscript is discussed in A. van der Hoeven, *Lambert ten Kate: De 'Gemeenschap tussen de Gottische spraeke en de Nederduytsche' en zijne onuitgegeven geschriften over klankkunde en versbouw* ('s Gravenhage 1896).

2 Principal sources for Ten Kate's biography are: C.L. ten Cate, *Lambert ten Kate Hermansz. (1674–1731). taalgeleerde en konstminnaar* (Utrecht 1987); J. Noordegraaf and M. van der Wal, 'Lambert ten Kate (1674–1731) and linguistics', introduction to L. ten Kate Harmensz., *Aenleiding tot de kennisse van het verhevene deel der Nederduitse sprake* (Alphen aan den Rijn 2001), pp. 2–32; R. Vermij, 'The formation of the Newtonian philosophy: the case of the Amsterdam mathematical amateurs', *British journal for the history of science* 36 (2003), pp. 183–200; H.J. Zuidervaart, *Van 'Konstgenoten' en hemelse fenomenen. Nederlandse sterrenkunde in de achttiende eeuw* (Rotterdam, 1999), p. 450. On the Mennonite context, see in particular: H.Th. van Veen, 'Devotie en esthetiek bij Lambert ten Kate', *Doopsgezinde bijdragen* 21 (1995), pp. 63–96.

3 Nettis became minister in Middelburg and practiced as eye doctor. In Middelburg he was a central figure in the local scientific culture, see: Zuidervaart, *'Konstgenoten'* (note 2), p. 392 (in particular note 247, p. 535).

4 L. ten Kate, 'Proef-ondervinding over de scheyding der coleuren, bevonden, door een prisma, in de volgende orde der muzyk-toonen; in navolging eener Proef-ondervinding in *Newtons gezigtkunde*: eertyds waargenomen, en nu uit de nalatenschap van *Lamb. ten Katen, Hz.* medegedeeld door den voorgem: *Joh: Nettis*', *Verhandelingen uitgegeeven door de Hollandse Maatschappy der Weetenschappen, te Haarlem*, part 3 (Haarlem 1757), pp. 17–30.

5 Ten Kate, 'Scheyding' (note 4), pp. 17–18. 'Newton berigt in zyn Boek over de *gezigt-kunde* (Boek I. Afdeel. II. *III. Deel.* Voorstel III. Proef VII.) pag. 104, ...'.

6 This is probably one of the weakest spots in the *Opticks* because Newton did not really substantiate – theoretically or empirically – this statement. The musical division of the spectrum was in fact the weak bid after Newton had failed to find a law of dispersion that met his standards. With hindsight this is exactly where his project of turning the science of colours mathematical foundered. For a complete account, see: A.E. Shapiro, 'Newton's "Achromatic" dispersion law: theoretical background and experimental evidence', *Archive for history of exact sciences* 21 (1979), pp. 91–128.

7 A.E. Shapiro (ed.), *The optical papers of Isaac Newton*, Vol. 1, *The Optical Lectures, 1670–1672* (Cambridge 1984), pp. 537–549; I. Newton, 'An hypothesis explaining the properties of light discoursed of in my several papers', in: Th. Birch, *The history of the Royal Society of London, for Improving of Natural Knowledge, from its first rise*, 4 vols (London 1756–1757), vol. 3, pp. 247–305.

8 Shapiro, 'Achromatic' (note 6), pp. 105–113.

9 P. Gouk, 'The harmonic roots of Newtonian science', in: J. Fauvel et al. (eds), *Let Newton be!* (Oxford 1988), pp. 101–126; H. Miedema, *Denkbeeldig schoon. Lambert ten Kates opvattingen over beeldende kunst,* 2 vols (Leiden 2006), vol. 2, p. 35. See Ten Kate's letters in this edition, vol. 1, p. 177, p. 197 and p. 202.

10 '*De Scheijding der Koleuren met de Prisma vloeijt zo teder ondereen, dat geen oog dit verschil tussen de omstaende Newtons deeling en de myne vermerken kan; waarom ik, vermits de Werken der Natuer, hoe meer ze gekent, hoe volmaeckter dat ze gevonden worden, de myne voor de egtste houde*.' Kate, 'Scheyding' (note 4), p. 21.

11 '*Hier nu egter vertoont ze [de Straelscheijding of Regenboogsche Coleurmaking] zig by dit Vlies reflecterende, zoo heerlyk, duijdelyk, en in haer oppersten graed, met Regenboog op Regenboog, en Octaef op Octaef: waervan de Oplossing ten uitersten merkwaerdig is*.' Ten Kate, 'Scheyding' (note 4), p. 25.

12 '... *waaruit een alleredelst Prisma-vormig Vlies geboren word:*'. Ten Kate, 'Scheyding' (note 4), p. 26.

13 A.E. Shapiro, *Fits, passions, and paroxysms. physics, method, and chemistry and Newton's theories of colored bodies and fits of easy reflection* (Cambridge 1993), pp. 199–207.
14 He gives page number 104. Book 1, part 2, Proposition III, Experiment VII is on pp. 91–93 in the original English edition of *Opticks* of 1704. In *Optice* of 1706 it is on pp. 103–106.
15 O.M. Lilien, *Jacob Christoph Le Blon 1667–1741: inventor of three- and four colour printing* (Stuttgart 1985).
16 F.J. Dijksterhuis, '"Will the eye be the sole judge?" "Science" and "Art" in the optical inquiries of Lambert ten Kate and Hendrik van Limborch around 1710', in E. Jorink and B. Ramakers (eds), *Art and science in the early modern Low Countries,* Netherlands Yearbook for History of Art/ Nederlands Kunsthistorisch Jaarboek 61 (Zwolle 2011) 308–331.
17 I. Newton, *Opticks* (London 1704), pp. 110–117 (Book I, Part II, Prop. V, Theorem IV, Exp. XV; and Prop. VI, Problem II).
18 The colors of the spectrum are represented by arcs on the circumference of the circle, whose lengths are based on the harmonic division of the spectrum. The portion of each color in the mixture is represented by a weight and the common center of gravity can then be determined. The radius through this point gives the position of the compound color on the circumference of the circle, and thus its position in the spectrum.
19 J. Le Clerc, 'Article VII. Optics (sic), … A Londres 1604. in 4. pagg. 356', *Bibliothèque Choisie* 9 (1706), pp. 245–319.
20 J. Le Clerc, 'Optics' (note 19), pp. 278–281. Newton's account of the rainbow again received ample attention.
21 F.J. Dijksterhuis, 'Reading up on the upticks. Refashioning Newton's theories of light and colors in eighteenth-century textbooks', *Perspectives on science* 16 (2008), pp. 309–327. Likewise Desaguliers, who also ignored Newton's account of colours in thin films.
22 J. Le Clerc, 'Optics' (note 19), pp. 304–319.
23 Ten Kate, *Beau ideal* (note 1), preface i.
24 J. Le Clerc, 'Article II. Livres Anglois. Pour trouver la vérité de la religion naturelle, par des raisons philosophiques', *Bibliotheque ancienne & moderne* 3–1 (1715), pp. 41–158; Ten Kate, *Schepper* (note 1).
25 Ten Kate, *Schepper* (note 1), pp. 48–49.
26 Ibidem, p. 121.
27 See also J. Gage, *Colour and culture: practice and meaning from antiquity to abstraction* (London 1993), pp. 168–171.
28 J.C. Le Blon, *Coloritto, or the harmony of coloring in painting: reduced to mechanical practice under easy precepts and infallible rules, together with some colour'd figures in order to render the said precepts and rules intelligible not only to painters but even to all lovers of painting* (London [1725]), p. 6.

29 Van Veen, 'Devotie' (note 2); Miedema, *Denkbeeldig schoon* (note 9), vol. 2, pp. 39–42.

30 Van Veen, 'Devotie' (note 2), pp. 79–95.

31 In particular, Ibidem, pp. 71–77.

32 Ten Kate, 'Klankkunde' (note 1). See also Van der Hoeven, *Onuitgegeven geschriften* (note 1).

33 I discuss the project and elaborate my argument about its significance for the historiography of optics in Dijksterhuis, 'Will the eye' (note 16).

34 L. ten Kate, (L.t.K.H.), 'Article VII. Lettre écrite à l'auteur de la B.A.&M.', *Bibliothèque ancienne & moderne* 8 (1717), 1st part, pp. 223–231. Citation on p. 223: *'je vous communicai qu'il y avoit ici, à Amsterdam, un Mr. Farenheit, qui fait plusieurs sortes de* Barometres *& de* Thermometres*, avec beaucoup plus d'exactitude, pour l'usage des Physiciens, que j'en aye trouvé jusqu'à présent'.*

35 Ten Kate did not refer to the publications of Hauksbee. For the history of barometric light, see E.N. Harvey, *A history of luminescence from the earliest times until 1900* (Philadelphia 1957), in particular pp. 271–277; D.W. Corson, 'Pierre Poliniere, Francis Hauksbee, and electroluminescence: a case of simultaneous discovery', *Isis* 59 (1968), pp. 402–413.

36 J. Picard, 'Experience fait à l'observatoire sur la barometre simple touchant un nouveau phenomene qu'on y a découvert', *Journal des sçavans* (25 May 1676), p. 112 (Paris edition); p. 126 (Amsterdam edition).

37 J. Bernoulli, 'Nouvelle maniere de rendre les baromètres lumineux', *Mémoires de l'Académie Royale des Sciences de Paris* 2 (1703), pp. 178–190; J. Bernoulli, 'Noveau phosphore', *Mémoires de l'Académie Royale des Sciences de Paris* 2 (1704), pp. 1–9; J. Bernoulli, 'Lettre de M. Bernoulli Professor à Groningue, touchant son noveau phosphore', *Mémoires de l'Académie Royale des Sciences de Paris* 2 (1704), pp. 135–146.

38 P. van der Star (ed. and trans.), *Fahrenheit's letters to Leibniz and Boerhaave* (Amsterdam 1983), pp. 1–18.

39 'Natuurkundige Lessen van Daniel Gabriel Fahrenheit', Leiden University Library, BPL 772. See Zuidervaart, *Konstgenoten* (note 2), p. 445 n.70. H. Snelders, 'De beoefening van de natuurkunde door de gegoede burgerij uit de achttiende eeuw', *Documentatieblad werkgroep achttiende eeuw* 31–32 (1976), pp. 3–24. The notes were made by Jacob Ploos van Amstel (1693–1758). His son Cornelis Ploos van Amstel (1726–1798) was an avid collector of art and instruments. He acquired large parts of Ten Kate's collection and copied a substantial part of his manuscript writings. The manuscript copies are in the library of the University of Amsterdam, 63 U.B.I.C. 21–24. See Miedema, *Denkbeeldig schoon* (note 9), vol. 1, pp. 14–15; Th. Laurentius et al. (eds), *Cornelis Ploos van Amstel (1726–1798). kunstverzamelaar en prentuitgever* (Assen 1980), pp. 97–99.

40 D. Fahrenheit, 'Berigt', transcribed in E. Cohen and W.A.T. Cohen-de

Meester, 'Daniel Gabriel Fahrenheit (geb. te Danzig 24 Mei 1686, overl. te 's-Gravenhage 16 Sept. 1736)', *Chemisch weekblad* 33 (1936), pp. 374–393 (separate copy: pp. 19–27). *'De Methode om Natuurkundige Wetenschappen, die met de Wiskonst verknogt zyn, door Experimenta of Proeven te demonstreeren, is onwederspreeklyk de beste.'*

41 In 1722 Fahrenheit had a letter published on ethereal phosphors, emphasizing the proof of quality these provided for barometers: D.G. Fahrenheit, 'Brief van den heere D.G. Fahrenheit aan Willem van Ranouw over de lichtende barometers, en over de kentekenen van een goeden barometer', *Kabinet der natuurlyke historien, wetenschappen, konsten en handwerken* 7 (1722), pp. 21–63.

42 'Natuurkundige Lessen' (note 39), f. 11r.

43 N. Hartsoeker, 'Lettre de Mr. Hartsoeker, sur quelques endroits des ouvrages de Mrs. Cheyne & Derham', *Bibliotheque ancienne & moderne* 8 (1712), pp. 303–350. See also C. Berkvens-Stevelinck, 'Nicolas Hartsoeker contre Isaac Newton ou pourquoi les planètes se meuvent-elles?', *Lias* 2 (1975), pp. 313–328.

44 'Natuurkundige lessen (note 39) f. 8r.

45 Ibidem, f. 34v.

46 Ibidem, ff. 52r-52v. *'Zijn eigen woorden luiden aldus. Nadat ik voor omtrent 9 jaren de Optique van den heere Newton gelezen had, beviel mij de Compositie van de voorbeschreven Verrekijker zo wel, dat ik maar naar gelegenheid haakte om een diergelijke werkstellig te maken, en vermits den heer Newton zo wel over het Metaal, als over het Glas in zijn werk klaagt, verkoos ik voor omtrent 6 Jaren een zeer hart gemaakt Staal tot de voorwerp Spiegel van Ses duim brandpunt, Rhijnlandse maat; en nadermaal het mij in 't gebruik wat ongemaklijk scheen om van ter zijden in de spiegel te kijken, zo maakte ik in 't midden van die Spiegel een rond gat, voorts stelde ik een klein bultig spiegeltje op zodanigen afstand van de Voorwerp Spiegel, dat de stralen der Voorwerpen (die van de groote spiegel gereflecteert wierden) voor de twedemaal afkaatsten naar de Opening, die in de groote Voorwerp Spiegel gemaakt was, bij welke opening de Stralen tot een beeltnis verzameld wierden.'*

47 Van der Star, *Letters* (note 38), pp. 66–71.

48 Cohen and Cohen-de Meester, 'Fahrenheit' (note 40), pp. 9–15; Van der Star, *Letters* (note 38), pp. 5–8.

49 G. Haase, 'Tschirnhaus und die sächsischen Glashütten in Pretzsch, Dresden und Glücksburg', in: W. Dolz and P. Plaßmeyer (eds), *Experimente mit dem Sonnenfeuer: Ehrenfried Walther von Tschirnhaus (1651–1708). Sonderausstellung im Mathematisch-Physikalischen Salon im Dresdner Zwinger vom 11 April bis 29 Juli 2001* (Dresden 2001), pp. 55–67.

50 He had been a nodal point to a circle of heterodox thinkers in the Dutch Republic. R.H. Vermij, 'De Nederlandse vriendenkring van E.W. von

Tschirnhaus', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 11 (1988), pp. 153–178.

51 K. Schillinger, 'Herstellung und Anwendung von Brennspiegeln und Brennlinsen durch Ehrenfried Walther von Tschirnhaus', in: Dolz and Plaßmeyer (eds), *Experimente* (note 49), pp. 43–54.

52 This is by no means a novel issue; it has been discussed from at least the 1970s (see the references in the notes). Nevertheless, the label 'Newtonianism' is still frequently used and often in a rather careless manner. I therefore find it appropriate to go into the matter again. Moreover, the reception of *Opticks* offers some additional perspectives on the matter.

53 See, for example, E. Ruestow, *Physics at seventeenth- and eighteenth-century Leiden: philosophy and the new science in the university* (The Hague 1973). In the history of science nuances may have developed, but the generic term 'Newtonianism' endures.

54 J. Schuster, 'The scientific revolution', in: R.C. Olby et al. (eds), *Companion to the history of modern science* (London 1990), pp. 217–242; R. Iliffe, 'Philosophy of science', in: R. Porter (ed.), *The Cambridge history of science,* Vol. 4*, eighteenth-century science* (Cambridge 2003), pp. 267–284.

55 This is even in the case in the quite lucid accounts of Heilbron and Hakfoort: J.L. Heilbron, *Electricity in the 17th and 18th centuries: a study of early modern physics* (Berkeley 1979); C. Hakfoort, 'Christian Wolff tussen Cartesianen en Newtonianen', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 5 (1982), pp. 27–38.

56 C. de Pater, *Petrus van Musschenbroek (1692–1761), een Newtoniaans natuuronderzoeker* (PhD-thesis, Utrecht 1979); R.E. Schofield, 'An evolutionary taxonomy of eighteenth-century Newtonianisms', *Studies in eighteenth-century culture* 7 (1978), pp. 175–192.

57 J. Gascoigne, 'Ideas of nature: natural philosophy', in: Porter, *Cambridge history* (note 54), pp. 285–304.

58 A case in question is Huygens' response in 1672 to Newton's 'New theory of white light and colours', that was not motivated by his different ideas of the ontology of light but by his material and intellectual expertise in telescope making. See F.J. Dijksterhuis, *Lenses and waves: Christiaan Huygens (1629–1695) and the mathematical science of optics in the seventeenth century* (Dordrecht 2004), pp. 83–92.

59 Coincidentally, in a response to Hakfoort and a defense of the use of categories like 'Newtonianism', Van Berkel explained that the criterion for historical concepts is not empirical correctness but narrative fruitfulness. K. van Berkel, 'Wat is er mis met het isme? Kanttekeningen bij een themanummer', *Tijdschrift voor de geschiedenis der geneeskunde, natuurwetenschappen, wiskunde en techniek* 5 (1982), pp. 118–125, on 124. The focus on natural philosophical systems probably is a product of twenti-

eth-century conceptions of natural science in which foundational theories are central. Projecting this in history presupposes paradigms to be the cornerstone of natural inquiry. Less orthodox dealings with systems is then often called 'eclectic', a term that explains little to nothing. In my view, one will look hard for a 'hard core' with 'Newtonians' or other 'ians'.

60 Schofield, 'Taxonomy' (note 56).

61 G. Wiesenfeldt, *Leeres Raum in Minervas Haus. Experimentelle naturlehre an der Universität Leiden, 1675–1715* (Amsterdam 2002), pp. 54–58.

62 D.M. Clark, *Occult powers and hypotheses: Cartesian philosophy under Louis XIV* (Oxford 1989).

63 Vermij, 'Formation' (note 2).

64 M. Evers, 'Pro Newtone et religione: de receptie van Newton en de Engelse fysicotheologen in de *Bibliotheqe Ancienne et Moderne* (1714–1727), *Documentatieblad achttiende eeuw* 20 (1988), pp. 247–267; E. Jorink, 'Honouring Sir Isaac, or, exorcising the ghost of Spinoza: some remarks on the success of Newton in the Dutch Republic', in: S. Ducheyne (ed.), *Future perspectives on Newton scholarship and the Newtonian legacy in eighteenth-century science and philosophy,* Verhandelingen van de Koninklijke Vlaamse Academie van België voor Wetenschappen en Kunsten (Brussel 2009), pp. 21–32, on pp. 26–31.

65 L.M. Principe, 'A revolution nobody noticed? Changes in early eighteenth-century chymistry', in: L.M. Principe (ed.), *New narratives in eighteenth-century chemistry: contributions from the first Francis Bacon workshop, 21–23 April 2005* (Dordrecht 2007), pp. 1–22.

66 R. Salverda, 'Newtonian linguistics', in: M.C. Davies, J.L. Floord, and D.N. Yeandle (eds), *'Proper words in proper places': studies in lexicology and lexicography in honour of William Jervies Jones* (Stuttgart 2001), pp. 115–132; Noordegraaf and Van der Wal, 'Lambert ten Kate and linguistics' (note 2), pp. 10–12. Jorink offers a more balanced interpretation, although he does not elaborate very much upon the roots of Dutch experimentalism: Jorink, 'Honouring Sir Isaac' (note 64), pp. 21–32.

67 Dijksterhuis, 'Reading up' (note 21).

68 L.L. Roberts, 'Going Dutch: situating science in the Dutch Enlightenment', in: W. Clark, J. Golinski and S. Schaffer (eds), *The sciences in Enlightened Europe* (Chicago 1999), pp. 350–388.

69 J.-F. Baillon, 'Two eighteenth-century translators of Newton's *Opticks*: Pierre Coste and Jean-Paul Marat', *Enlightenment and dissent* 25 (2009), pp. 1–28

70 Dijksterhuis, 'Reading up' (note 21).